

A Visualization Tool for Illustrating Scaling Hierarchy of Geographic Features

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Many geographic features can be investigated from the perspective of complex networks, which consist of nodes for individual geographic features, and links for their relationship. This complex network differs fundamentally from their simple counterparts, i.e. regular networks. The major difference between complex and simple networks lies in node degrees. The degrees of nodes in a regular network vary little from one node to another. In contrast, the degrees of nodes in a complex network such as small-world (Watts and Strogatz 1998) and scale-free networks (Barabási and Albert 1999) tend to be very heterogeneous. The degrees in such complex networks often exhibit a scaling hierarchy, indicating that far more less-connected nodes than well-connected ones. To visualize such structure of complex networks, it is important to reveal the underlying scaling hierarchy of nodes and their relationships. However, conventional network visualization methods, e.g. graph drawing (Fruchterman and Reingold 1991), failed to do so because they either focus on small and simple networks, or ignore the inherent hierarchies. This paper intends to introduce an effective visualization tool for illustrating underlying scaling hierarchy of geographic features.

The visualization tool is developed from an algorithm which creates a radial layout for showing the scaling hierarchy based on head/tail breaks - a classification and visualization scheme for data with a heavy tailed distribution (Jiang 2013 and 2015). Given a complex network, the arithmetic mean of nodes' degree splits all the nodes into the head (the small percentage of nodes with a degree above the mean) and the tail (the large percentage of nodes with a degree below the mean). This process goes iteratively for the head part until the head part is no longer a minority. The obtained tails during the splitting process together with the final head form a scaling hierarchy of far more less-connected nodes than well-connected ones. We allocate the final head in the center, which is followed by tails ring by ring in a radial layout. In other words, the nodes in the center are the most connected, whereas the nodes on the outmost ring are at the least connected. The links among the nodes are divided into two categories: those across levels and those within the same level. Formally, the algorithm is described using the following function.

```
Function RadialLayout (complex network)
// network is to be visualized through a radial layout
Derive the network's scaling hierarchy using head/tail breaks;
Foreach node at the highest hierarchical level:
    Find every other reachable node across different levels;
    Generate its branch and mark the visited nodes;
    Assign each branch within the space given by each sector;
End Function
```

To illustrate, we visualized the open flights data containing 6,977 airports and 67,690 route records (downloaded at <http://openflights.org/data.html>). Based on the flight information, we built up the flight network and found that it is a scale-free network. We derived the hierarchical levels of airports according to their in-degrees (Figure 1a). The resulting complex network (Figure 1d) consists of the foreground and background displaying respectively the relationships across levels (blue lines) and the relationships within the same level (gray lines). Compared to the conventional graph layouts shown in Figure 1b and 1c, the

complex network shows clearly the scaling hierarchies of the global flight network. From the radial layout, we can see that how diverse the nodes are in terms of their in-degrees. In addition, if we zoom into each ring, we can see that how nodes are adaptive with each other with similar in-degrees. In this connection, the visualization tool contributes to enhancing our understanding of the structure of a complex network. This is what makes our visualization tool effective and unique for examining geographic features from a complex network perspective.

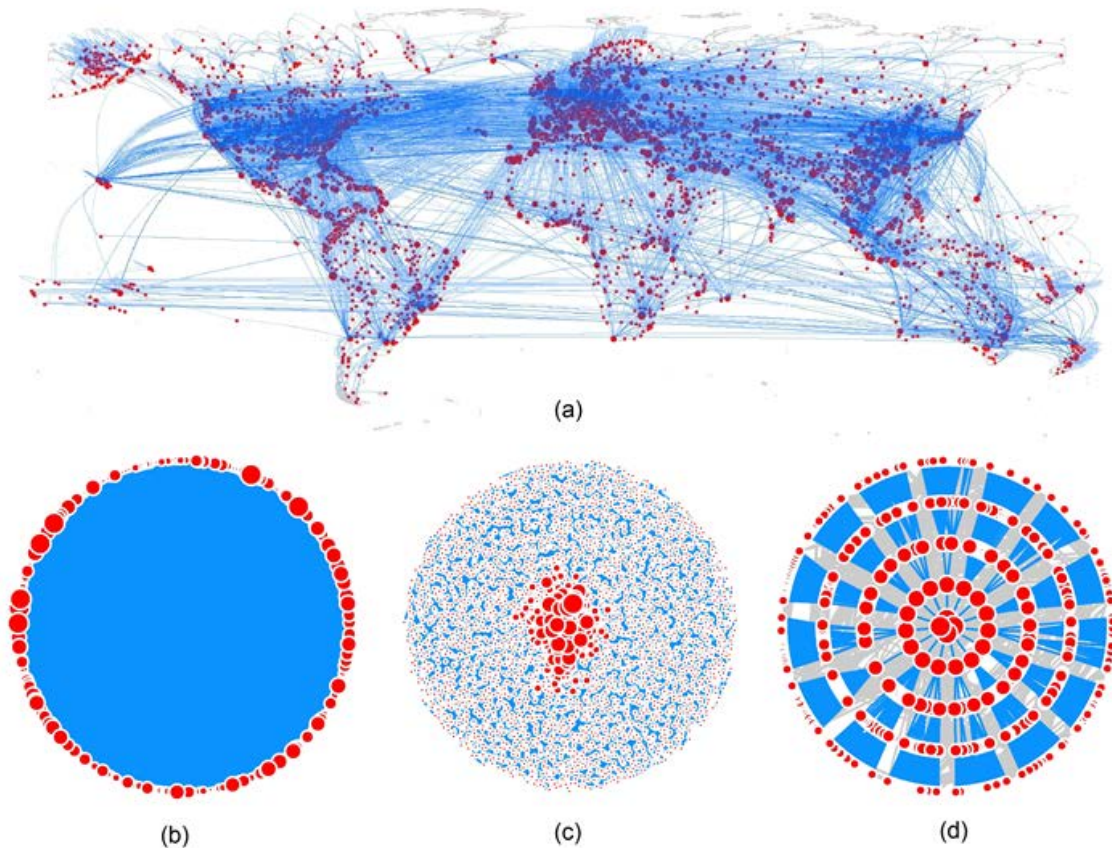


Figure 1: (Color online) The open flight network in the geographic layout (a), circular layout (b), force directed layout (c) and radial layout from the visualization tool (d) (Note: the dot size is corresponding to the airport hierarchical levels determined by node in-degrees using head/tail breaks)

Keywords: Head/tail breaks, complex networks, scaling hierarchy

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